Massachusetts Low Demand Analysis

Second Stakeholder Meeting

(Slides updated 10-30-14 at 8 am)

October 30, 2014

Meg Lusardi, Acting Commissioner, DOER

Farhad Aminpour, Director - Energy Markets Division

Dr. Jonathan Raab, Raab Associates, Ltd.

Dr. Elizabeth A. Stanton, Synapse Energy Economics

Welcome & Purpose of Project

Purpose of the Project

- Consider various solutions to address Massachusetts' short and long-term energy needs, taking into account greenhouse gas reductions, economic costs and benefits, and system reliability

Review of Agenda & Meeting Objectives

Objectives of This Meeting

- Key Modeling Assumptions
  - Update including additional detail from Synapse
  - Get small group and individual questions addressed by Synapse
  - Individual comments on key modeling assumptions
- Feasibility Analysis
  - Presentation from Synapse on feasibility analysis approach and results
  - Clarifying questions
  - Comments from on feasibility analysis from stakeholder groups
- Next Steps (including written comments, next steps in analysis, and next meeting)

Overview of Agenda

Time	Topic	Speaker
9:30 AM	**Welcome**	Meg Lusardi, DOER
9:35	**Review of Agenda & Meeting Objectives**	Dr. Jonathan Raab
9:45	**Key Modeling Assumptions** A. Presentation [Winter Peak Event; Base Case; & Sensitivity Assumptions (Gas Prices & Incremental Canadian Transmission)] B. Small Group Discussion/Group Questions C. Additional Individual Questions/Comments	Dr. Liz Stanton
11:45	Lunch (provided)	

Overview of Agenda

12:30	**Feasibility Analysis** [Approach; Supply Curve; & Appropriate Threshold] A. Presentation B. Clarifying Questions	Synapse Team
2:00	Break	
2:15	**Feasibility Analysis** (continued) A. Small Group Discussion/Report Out	Dr. Jonathan Raab
3:30 PM	**Next Steps: Modeling and Stakeholder Process**	Dr. Liz Stanton & Dr. Jonathan Raab
3:45 PM	**Adjourn**	

Ground Rules

- State your name and affiliation when speaking
- Share your feedback with affirmations or alternatives
- Be succinct in your comments/questions
- Silence phones
- Dial-in participants will be muted during the presentations; You will have an opportunity to ask clarifying questions at the end of the questions in the room

Overview of the Stakeholder Process

Overview of Stakeholder Process

- Materials will be available on Synapse's website at: http://synapse-energy.com/project/massachusetts-low-demand-analysis
- All meetings are open to the public
- High-level summaries of Stakeholder Meetings will be provided
- This is not a consensus-seeking process
  - Input will be gathered at three Stakeholder Meetings
  - Written comments can be submitted to DOER within three business days after meetings
  - Email: lowdemandstudy@state.ma.us
  - Input will be considered by DOER and Synapse

Overview of Stakeholder Process (cont.)

- October 15, 9am-noon – **Stakeholder Meeting**: Provide an overview of the process and key resources alternatives
  - October 20 – Written comments due to DOER (lowdemandstudy@state.ma.us)
- October 30, 9:30am-4pm – **Stakeholder Meeting**: Review results of feasibility study of alternative resource penetration and supply curves for 2015, 2020, 2030; Detailed discussion of modeling process
  - Location: Hearing Room A at DPU, One South Station, Boston
  - Nov. 4 – Written comments due
- November 20, 9am-4pm – **Stakeholder Meeting**: Review results of modeling runs and their implications; Present an outline of final report
  - Location: TBD
  - November 25 – Written comments due
- December 23 – **Final report** released

Key Modeling Assumptions

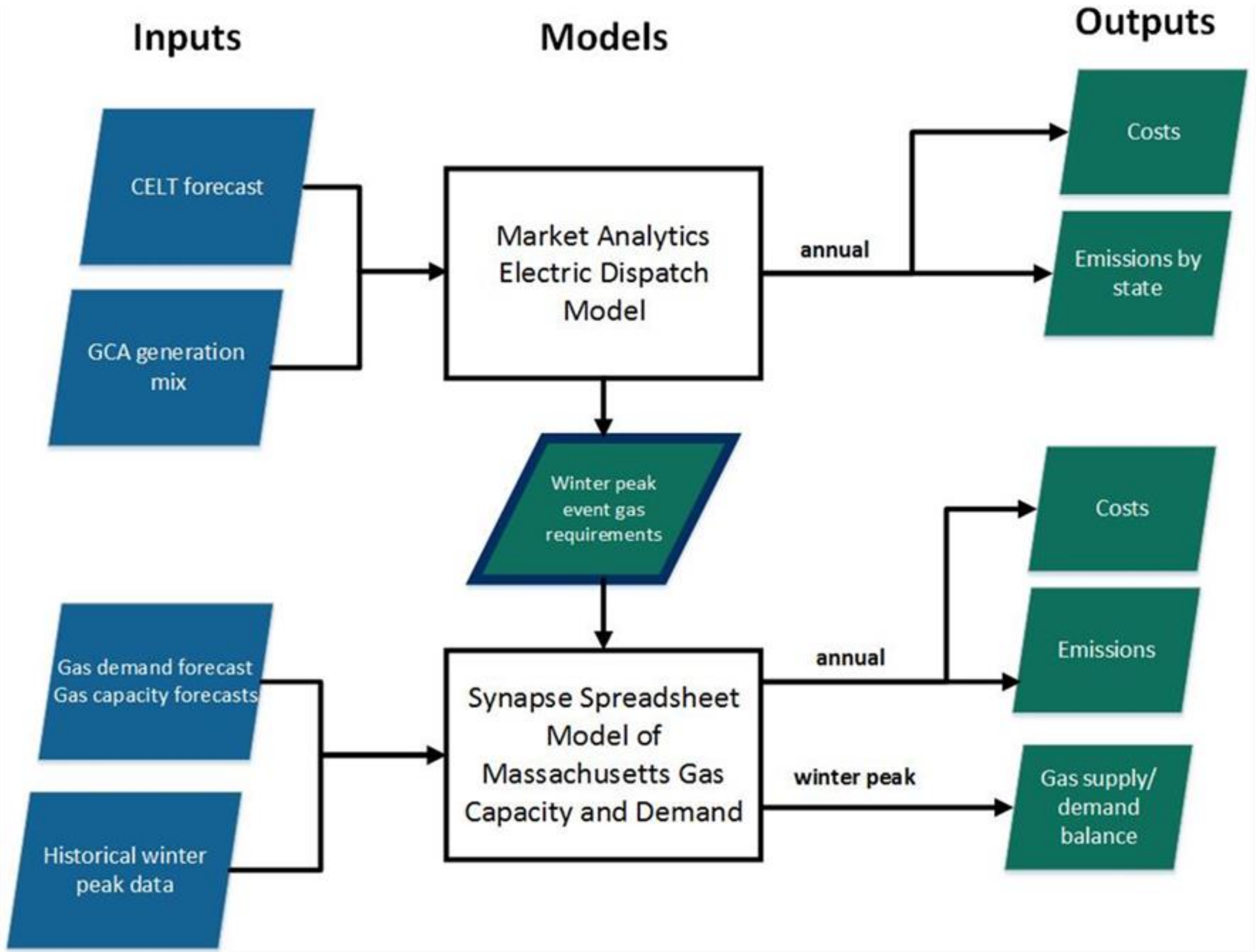
Key Modeling Assumptions

- Modeling objectives
- Model design
- Winter peak event
- Scenarios and sensitivities
  - Base case
  - Low energy demand case
  - Natural gas price sensitivity
  - Incremental Canadian transmission sensitivity

Modeling Objectives

- Synapse will use Market Analytics together with purpose-built Excel-based spreadsheets to analyze the following for each year under analysis:
  - Sufficiency of gas pipeline capacity under winter peak event conditions: We will model New England gas supply and demand under conditions defined by a winter peak event (as defined below), taking account of the impact on energy storage of a "cold snap" or series of winter peak days.
  - Annual costs and emissions: We will model fuel use, electric generation, energy costs, and greenhouse gas emissions on an annual basis. Annual costs and emissions will be modeled based on expected (most likely) weather conditions, not extreme conditions. These expected weather conditions will include the occurrence of winter high demand events.

Model Design



Winter Peak Event

Our analysis of the sufficiency of Massachusetts natural gas capacity will be conducted through the lens of a “winter peak event”—a series of particularly cold winter days under which high gas demands have the greatest potential to exceed gas capacity. For the purposes of this analysis, a winter peak event is defined as follows:

- Capacity and demand in the peak hour of an expected future “design day”.
- Gas requirements for electric generation will represent the coincident peak with LDCs design day: for each year, the highest gas requirement for a January day from 6 to 7pm.
- Sufficiency of natural gas capacity will take into account the effects of a cold snap of 12 days.

Scenarios and Sensitivities

	No Incremental Hydro			2,400-MW Incremental Hydro
	Reference NG Price	**Low NG Price**	**High NG Price**	**Reference NG Price**
Base Case	Base Case No Hydro Ref NG Price	Base Case No Hydro Low NG Price	Base Case No Hydro High NG Price	Base Case 2,400-MW Hydro Ref NG Price
Low Case	Low Case No Hydro Ref NG Price	Low Case No Hydro Low NG Price	Low Case No Hydro High NG Price	Low Case 2,400-MW Hydro Ref NG Price

Scenarios: Base Case

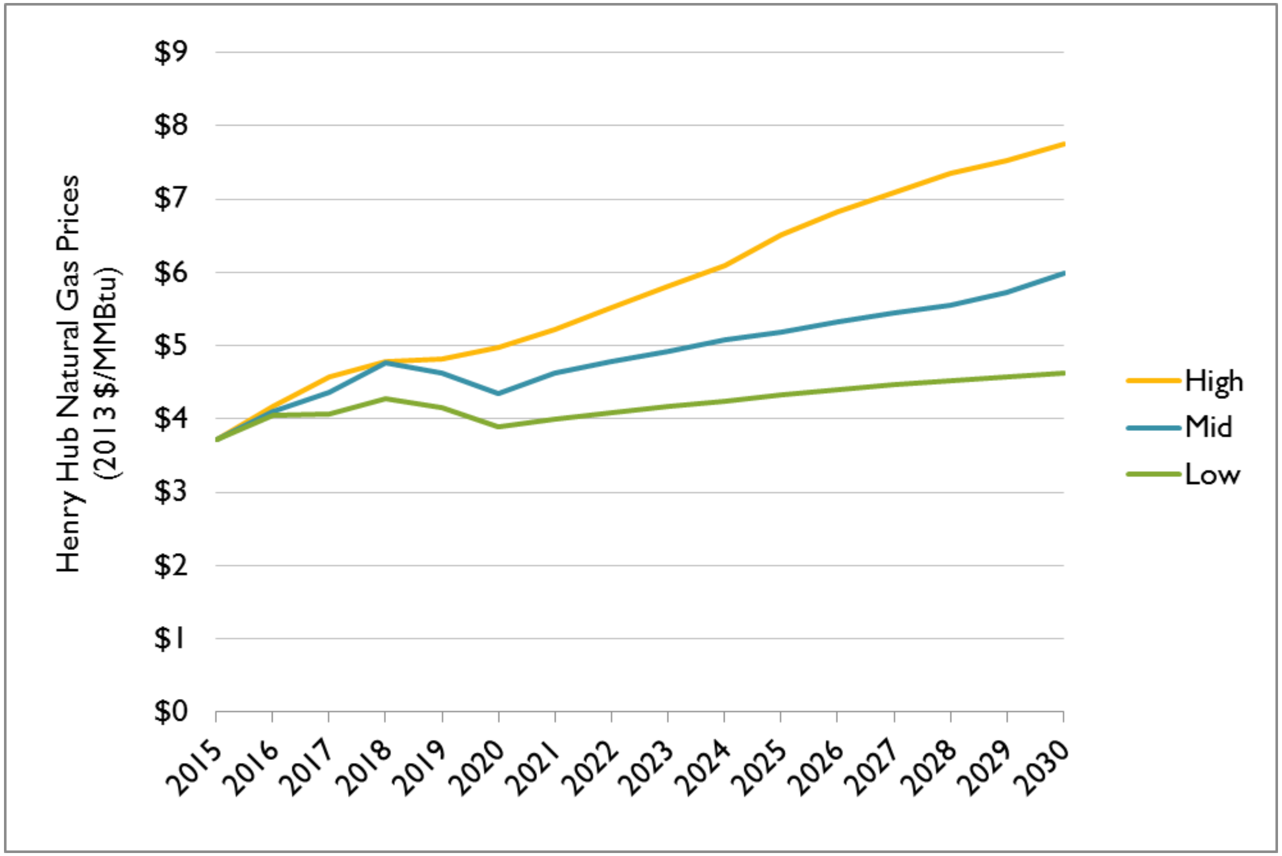
- Energy resource mix and energy demand will model expected conditions under existing policy measures, a reference natural gas price, and the assumption that there will be no incremental electric transmission from Canada in the 2015 to 2030 period.
- Electric and gas load will be modeled using existing, well-recognized projections and appropriate adjustments to these forecasts based on well-known critiques.
- Electric generation resource mix will be modeled using the Market Analytics to provide an accurate presentation of Green Communities Act policies, all New England state RPS policies by class, the ISO-NE Winter Reliability program with its current sunset date, the recent DPU order 14-04 on time-varying rates, and forecasted LNG usage.
- Carbon allowance prices: RGGI forecast to 2020, Synapse forecast 2020-2030

Scenarios: Low Energy Demand Case

- Designed by making adjustments to the base case.
- In the low energy demand case, all alternative resources will be utilized to the greatest extent that is determined to be simultaneously technically and economically feasible (the methodology for this feasibility assessment is described below).
- In this scenario, changes to public policy will be assumed for Massachusetts only and not for the neighboring states.
- Carbon allowance prices: RGGI forecast to 2020, Synapse forecast 2020-2030

Natural Gas Price Sensitivity

- We will investigate the sensitivity of modeling results to both increases and decreases in the expected price of natural gas



Incremental Canadian Transmission Sensitivity

- We will investigate the sensitivity of modeling results to the addition of 2,400 MW of new, incremental transmission from Canada to the New England hub.
- 1,200 MW by 2018; an additional 1,200 MW by 2022
- Winter peak day capacity factor: 75%
- Winter peak hour capacity: 100%

Incremental Canadian Transmission Sensitivity

- We will investigate the sensitivity of modeling results to the addition of 2,400 MW of new, incremental transmission from Canada to the New England hub.

CA Hydro HVDC 1	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	0%	0.0	$0	$0	0.0	0.0
2020	67%	1,200	$100	$1,199	84,516,480	10,800
2030	67%	1,200	$100	$1,199	84,516,480	10,800

CA Hydro HVDC 2	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	0%	0.0	$0	$0	0.0	0.0
2020	0%	0.0	$0	$0	0.0	0.0
2030	50%	1,200	$147	$1,759	63,072,000	10,800

Correction to Heat Rate

- Throughout the analysis presented today we calculate the displaced natural gas MMBtu from MWh-producing electric resources using a 12 MMBtu/MWh heat rate. This is the heat rate associated with the generator that is marginal during the **peak** hours of the year.
- An alternate heat rate option for calculating the annual natural gas MMBtu displaced by new electric resources could be the **monthly average** implied marginal heat rate in ISO New England (8.4 MMBtu/MWh in 2013).
- This change would effect annual energy produced by alternative electric resources as well as the energy produced by incremental Canadian transmission.
- Data source: 2013 Assessment of the ISO New England Electricity Markets. Potomac Economics. June 2014. Page 44.

Small Group Break-Out

Mixed Break Out Groups

- Introductions (name, organization)
- Share perspectives with each other on Synapse proposed approach/assumptions regarding:
  - Winter peak event
  - Scenarios: Base case and Low demand case
  - Sensitivities: Natural gas price and Incremental transmission
- Identify 2-3 “group” questions to ask Synapse (and 1-2 people to ask the questions:
- When we get back together in 30 minutes:
  - Synapse will respond to Group questions (30 minutes)
  - Followed by any additional “individual” questions and comments (30 minutes)

Q&A: Key Modeling Assumptions and Comments

Lunch

Feasibility Analysis

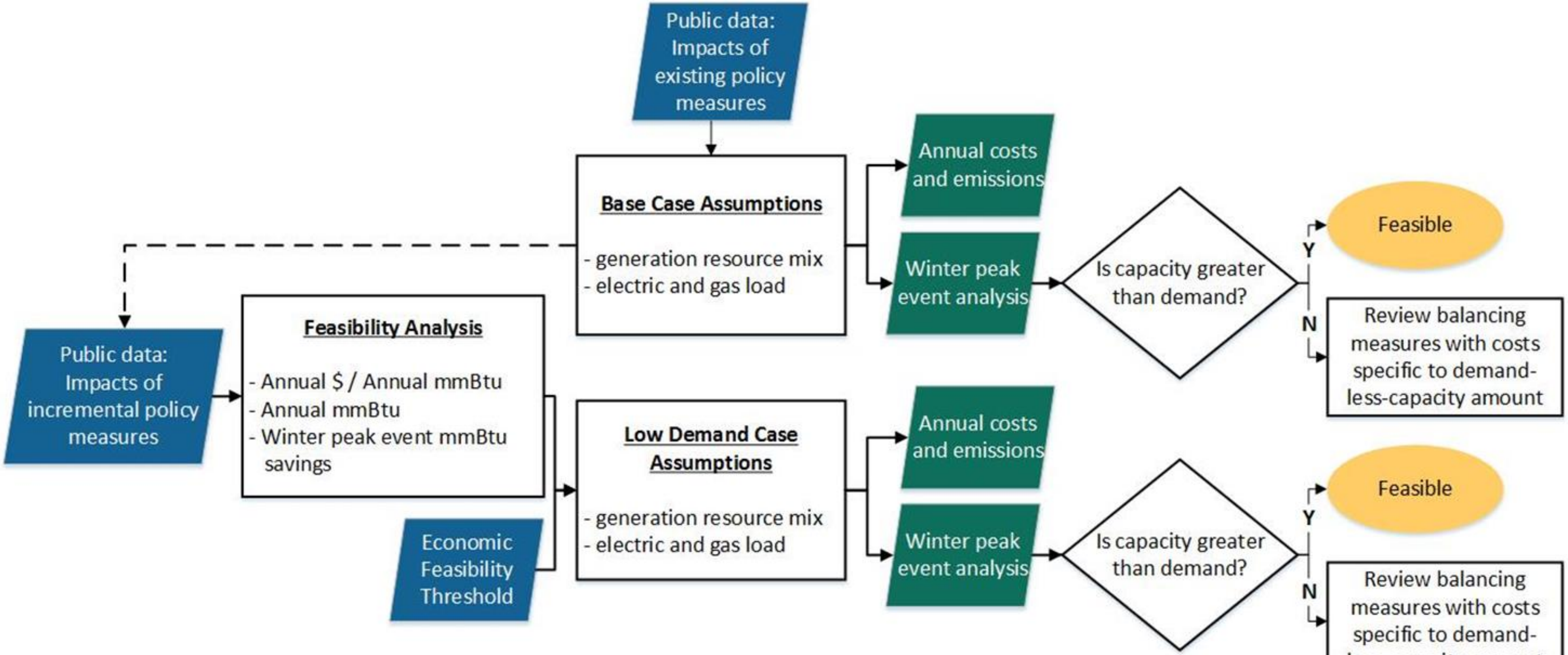
Feasibility Analysis

- Resource selection for low energy demand case
- Feasibility analysis design
- Avoided costs
- Resource assessments
- Threshold for economic feasibility
- Feasibility analysis results

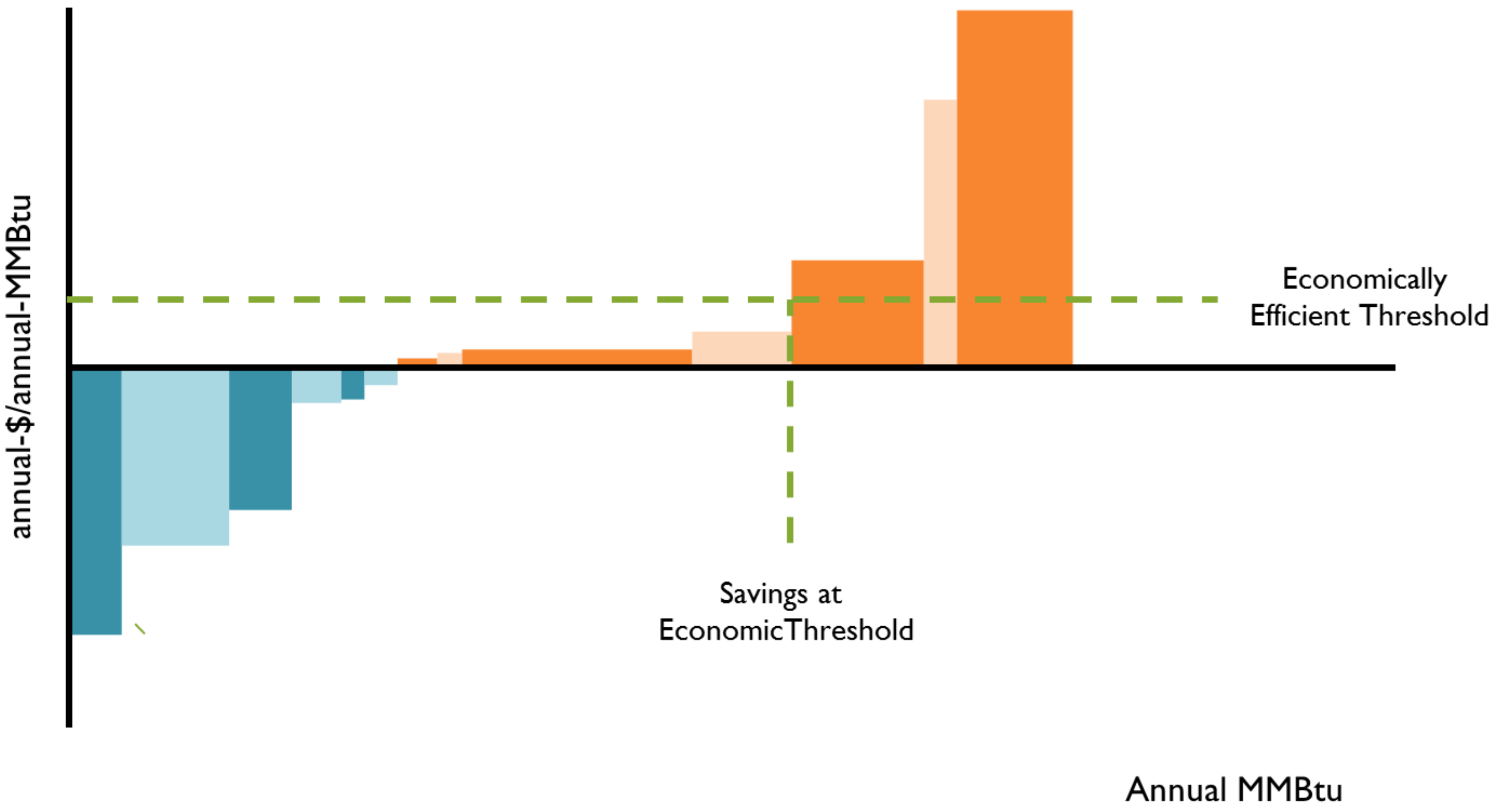
Resource Selection

- In the 2015, 2020, and 2030 feasibility analyses for alternative resources, annual-$/annual-MMBtu for each measure determined to be technically feasibility in that year will be compared to a threshold for economic feasibility.
- Resources will be assessed as either less or more expensive that then selected threshold:
  - ***If annual-$/annual-MMBtu is less costly than economic feasibility threshold:*** Resources that are less expensive than the threshold will be included in the determination of the electric generation resource mix and electric and gas loads in the low energy demand case.
  - ***If annual-$/annual-MMBtu is more costly than economic feasibility threshold:*** Resources that (a) are more expensive than the threshold and (b) contribute MMBtu savings during the winter peak event hour will be held in reserve for use in the final gas capacity and demand balancing step of modeling.

Feasibility Analysis Design



Example Supply Curve



Avoided Costs

- In this feasibility analysis all measures are assessed in terms of their total annual costs in the study year net of their avoided costs in that same year.
- For energy efficiency resources: (1) avoided energy, capacity and T&D from the AESC 2013 base case; (2) avoided costs of GWSA compliance (DPU 14-86)
- For non-energy-efficiency resources: avoided energy, environmental compliance, capacity and T&D from the AESC 2013 base case
- All avoided costs updated to reflect natural gas prices used in this study
- Feasibility analyses for low and high gas price sensitivities will use the appropriate natural gas prices

Avoided Cost Assumptions

		Electric Resources			**Gas Resources**	
		Energy Efficiency	*Non-EE, Distributed*	*Non-EE, Utility-Scale*	*Energy Efficiency*	*Non-EE, Distributed*
Energy	*$/MWh*	AESC 2013 Electric	AESC 2013 Electric	AESC 2013 Electric, Adj. for line losses	AESC 2013 Natural Gas	AESC 2013 Natural Gas
Environmental Compliance	*$/MWh*	DPU 14-86	AESC 2013 Electric	AESC 2013 Electric	DPU 14-86	None
Capacity	*$/kW*	AESC 2013 Electric	AESC 2013 Electric	AESC 2013 Electric	AESC 2013 Natural Gas	AESC 2013 Natural Gas
Transmission and Distribution	*$/kW*	AESC 2013 Electric	AESC 2013 Electric	None	AESC 2013 Natural Gas	AESC 2013 Natural Gas

Resource Assessments

Resource Assessment Overview

- The assessment of technical feasibility has been drawn from many publically available resources.
- Note that, for all of the summary feasibility tables presented here, resource capacity in each year is:
  - Incremental to the base case
  - Incremental to previous years (i.e. “2020” is 2016 to 2020 and “2030” is 2021 to 2030

Wind: On-Shore 10 kW or less

Wind (<10 kW)	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	16%	1.0	$656	$7,866	16,819	4.2
2020	16%	100	$557	$6,683	1,681,920	420
2030	16%	200	$444	$5,331	3,363,840	840

Data sources:

- Based personal communications with Urban Green Energy
- To represent the levelized cost of new transmission necessary to deliver incremental wind from Maine south to the major New England load centers we assume a real, levelized cost of new transmission of $35 per MWh, based on a cost of $2.15 billion for 1,200 MW of capacity recovered over 30 years. (Hornby, Rick, et al., *Memorandum: Incremental Benefits and Costs of Large-Scale Hydroelectric Energy Imports*, prepared by Synapse Energy Economics for the Massachusetts Department of Energy Resources, November 1, 2013.)

Wind: On-Shore 10 to 100 kW

Wind (<100 kW)	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	25%	1.0	$123	$1,473	26,280	4.2
2020	25%	100	$68	$820	2,628,000	420
2030	25%	300	$19	$226	7,884,000	1,260

Data sources:

- Based personal communications with Northern Power
- To represent the levelized cost of new transmission necessary to deliver incremental wind from Maine south to the major New England load centers we assume a real, levelized cost of new transmission of $35 per MWh, based on a cost of $2.15 billion for 1,200 MW of capacity recovered over 30 years. (Hornby, Rick, et al., *Memorandum: Incremental Benefits and Costs of Large-Scale Hydroelectric Energy Imports*, prepared by Synapse Energy Economics for the Massachusetts Department of Energy Resources, November 1, 2013.)

Wind: On-Shore >100 kW, Class 5

Large Wind C5	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	41%	200	$38	$455	8,619,840	840
2030	42%	480	$14	$171	21,192,192	2,016

Data sources:

- Based on National Renewable Energy Laboratory (NREL) supply curves for New England wind regions
- To represent the levelized cost of new transmission necessary to deliver incremental wind from Maine south to the major New England load centers we assume a real, levelized cost of new transmission of $35 per MWh, based on a cost of $2.15 billion for 1,200 MW of capacity recovered over 30 years. (Hornby, Rick, et al., Memorandum: Incremental Benefits and Costs of Large-Scale Hydroelectric Energy Imports, prepared by Synapse Energy Economics for the Massachusetts Department of Energy Resources, November 1, 2013.)

Wind: On-Shore >100 kW, Class 4

Large Wind C4	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	n/a	0.0	n/a	n/a	n/a	n/a
2030	40%	800	$21	$247	33,638,400	3,360

Data sources:

- Based on National Renewable Energy Laboratory (NREL) supply curves for New England wind regions
- To represent the levelized cost of new transmission necessary to deliver incremental wind from Maine south to the major New England load centers we assume a real, levelized cost of new transmission of $35 per MWh, based on a cost of $2.15 billion for 1,200 MW of capacity recovered over 30 years. (Hornby, Rick, et al., Memorandum: Incremental Benefits and Costs of Large-Scale Hydroelectric Energy Imports, prepared by Synapse Energy Economics for the Massachusetts Department of Energy Resources, November 1, 2013.)

Wind: Off-Shore

Offshore Wind	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	44%	800	$133	$1,591	37,002,240.0	3,360
2030	45%	1,600	$66	$788	75,686,400	6,720

Data sources:

- Based on National Renewable Energy Laboratory (NREL) supply curves for New England wind regions

Solar PV: Residential

Residential PV	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	13%	0.2	$100	$1,198	3,416	0.0
2020	13%	5.0	$90	$1,084	68,328	0.0
2030	13%	200	$6	$75	3,416,400	0.0

Data sources:

- Based on cost and capacity factor assumptions for 2015 and 2020 are based on work done in 2013 for DOER (http://www.mass.gov/eea/docs/doer/rps-aps/doer-post-400-task-1.pdf)
- 2030 assumptions are Synapse estimates

Solar PV: Commercial

Commercial PV	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	14%	1.6	$75	$905	30,275	0.0
2020	14%	50	$75	$905	946,080	0.0
2030	14%	800	-$4	-$48	15,137,280	0.0

Data sources:

- Based on cost and capacity factor assumptions for 2015 and 2020 are based on work done in 2013 for DOER (http://www.mass.gov/eea/docs/doer/rps-aps/doer-post-400-task-1.pdf)
- 2030 assumptions are Synapse estimates

Solar PV: Utility-Scale

Utility-Scale PV	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	15%	16	$76	$911	309,052.8	0.0
2030	15%	160	$10	$116	3,090,528	0.0

Data sources:

- Based on cost and capacity factor assumptions for 2015 and 2020 are based on work done in 2013 for DOER (http://www.mass.gov/eea/docs/doer/rps-aps/doer-post-400-task-1.pdf)
- 2030 assumptions are Synapse estimates

Non-Powered Hydro Conversion

Converted Hydro	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	38%	0.5	-$25	-$295	20,000	5.7
2020	38%	61	-$37	-$449	2,440,000	695
2030	38%	56	-$60	-$724	2,240,000	638

Data sources:

- Based on a Ohio Case study of converting a dam site to generate electricity and the U.S. Energy Information Adminstration's (EIA's) *Annual Energy Outlook* capital and operating costs forecast. (http://www.hydro.org/tech-and-policy/developing-hydro/powering-existing-dams/; http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf)

Landfill Gas

Landfill Gas	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	78%	0.3	-$37	-$442	24,750	3.4
2020	78%	20	-$46	-$552	1,650,000	228
2030	78%	6	-$68	-$820	495,000	68

Data sources:

- Based on the 2012 U.S. Environmental Protection Agency's *Landfill Gas Energy* study . (http://epa.gov/statelocalclimate/documents/pdf/landfill_methane_utilization.pdf)

Anaerobic Digestion

Anaerobic Digestion	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	90%	0.3	-$53	-$640	28,382	3.4
2020	90%	20	-$67	-$807	1,892,160	228
2030	90%	6	-$96	-$1,155	567,648	68

Data sources:

- Based on a 2003 Wisconsin case study presented in the *Focus on Energy Anaerobic Digester Methane to Energy* statewide assessment. (http://www.mrec.org/pubs/anaerobic_report.pdf)

Energy Storage: Pumped Hydro

Pumped Hydro	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	15%	560	$109	$1,307	8,830,080	6,384
2030	15%	560	$84	$1,007	8,830,080	6,384

Data sources:

- Based on a U.S Department of Energy (DOE) and Electric Power Research Institute (EPRI) 2013 *Electricity Storage Handbook*. Table B-12. (http://www.sandia.gov/ess/publications/SAND2013-5131.pdf)

Energy Storage: Battery

Battery Storage	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	15%	40	$257	$3,086	630,720	456
2020	15%	200	$217	$2,599	3,153,600	2,280
2030	15%	1,200	$122	$1,467	18,921,600	13,680

Data sources:

- Based on a U.S Department of Energy (DOE) and Electric Power Research Institute (EPRI) 2013 *Electricity Storage Handbook*. Table B-12. (http://www.sandia.gov/ess/publications/SAND2013-5131.pdf)

Biomass: Class 1

Biomass Power CI	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	80%	20	$27	$322	1,681,920	228
2030	80%	20	$5	$55	1,681,920	228

Data sources:

- Based on a on analyses by EIA, Black & Veatch, and Office of Energy Efficiency and Renewable Energy (EERE). (http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf; http://bv.com/docs/reports-studies/nrel-cost-report.pdf; http://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf)

Biomass: Class 2

Biomass Power C2	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	80%	40	$44	$530	3,363,840	456
2030	80%	40	$22	$262	3,363,840	456

Data sources:

- Based on a on analyses by EIA, Black & Veatch, and Office of Energy Efficiency and Renewable Energy (EERE). (http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf; http://bv.com/docs/reports-studies/nrel-cost-report.pdf; http://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf)

Biomass: Class 3

Biomass Power C3	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	80%	40	$131	$1,566	3,363,840	456
2030	80%	60	$108	$1,299	5,045,760	684

Data sources:

- Based on a on analyses by EIA, Black & Veatch, and Office of Energy Efficiency and Renewable Energy (EERE). (http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf; http://bv.com/docs/reports-studies/nrel-cost-report.pdf; http://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf)

Biomass: Class 4

Biomass Power C4	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	80%	50	$175	$2,102	4,204,800	570
2030	80%	70	$153	$1,835	5,886,720	798

Data sources:

- Based on a on analyses by EIA, Black & Veatch, and Office of Energy Efficiency and Renewable Energy (EERE). (http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf; http://bv.com/docs/reports-studies/nrel-cost-report.pdf; http://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf)

Combined Heat and Power: 500 kW units

Small CHP	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	85%	5	-$15	-$179	446,760	57
2020	85%	35	-$22	-$260	3,127,320	399
2030	85%	65	-$50	-$598	5,807,880	741

Data sources:

- Based on ICF's 2013 *The Opportunity for CHP in the U.S.* report. (http://www.aga.org/Kc/analyses-and-statistics/studies/efficiency_and_environment/Documents/The%20Opportunity%20for%20CHP%20in%20the%20United%20States%20-%20Final%20Report.pdf)

Combined Heat and Power: 12.5 MW units

Large CHP	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0	n/a	n/a	n/a	n/a
2020	85%	25	-$52	-$621	2,233,800	285
2030	85%	50	-$76	-$918	4,467,600	570

Data sources:

- Based on ICF's 2013 *The Opportunity for CHP in the U.S.* report. (http://www.aga.org/Kc/analyses-and-statistics/studies/efficiency_and_environment/Documents/The%20Opportunity%20for%20CHP%20in%20the%20United%20States%20-%20Final%20Report.pdf)

Electric Energy Efficiency: Residential

Res. Electric EE	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	55%	128	-$31	-$377	7,399,840	845
2030	55%	47	-$53	-$633	2,741,953	313

Data sources:

- Based on LBNL's 2013 *The Future of Utility Customer-Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025.*

Electric Energy Efficiency: C&I

CI Electric EE	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	55%	278	-$98	-$1,181	16,085,421	1,836
2030	55%	641	-$120	-$1,439	37,071,520	4,232

Data sources:

- Based on LBNL's 2013 *The Future of Utility Customer-Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025.*

Electric Energy Efficiency: Low Income

LI Electric EE	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	55%	15	$39	$469	893,944	102
2030	55%	23	$19	$224	1,353,072	154

Data sources:

- Based on LBNL's 2013 *The Future of Utility Customer-Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025.*

Electric Demand Response

Elec DR	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	400	$373	$4,475	115,200	4,800
2020	n/a	400	$360	$4,316	115,200	4,800
2030	n/a	400	$338	$4,058	115,200	4,800

Data sources:

- Based on FCM auctions

Winter Reliability Program

Winter Reliability	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	n/a	n/a	n/a	n/a	n/a
2020	n/a	n/a	$3	$36	29,434	0.00
2030	n/a	n/a	$3	$36	29,434	0.00

Data sources:

- Based on Synapse assessment of feasibility of extending ISO-NE's Winter Reliability program

Heat Pumps: Air Source

AS Heat Pump	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	n/a	n/a	$18	15,768	34
2020	n/a	n/a	n/a	$20	315,360	684
2030	n/a	n/a	n/a	$26	1,576,800	3,420

Data sources:

- Based on Navigant's 2013 *Incremental Cost Study Phase Two Final Report*, the *Commonwealth Accelerated Renewable Thermal Strategy* and information from vendors. (http://www.neep.org/sites/default/files/products/NEEP%20ICS2%20FINAL%20REPORT%202013Feb11-Website.pdf; http://www.mass.gov/eea/docs/doer/renewables/thermal/carts-report.pdf)

Heat Pumps: Ground Source

GS Heat Pump	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	n/a	n/a	$15	1,577	3.4
2020	n/a	n/a	n/a	$16	63,072	137
2030	n/a	n/a	n/a	$21	157,680	342

Data sources:

- Based on Navigant's 2013 *Incremental Cost Study Phase Two Final Report*, the *Commonwealth Accelerated Renewable Thermal Strategy* and information from vendors. (http://www.neep.org/sites/default/files/products/NEEP%20ICS2%20FINAL%20REPORT%202013Feb11-Website.pdf; http://www.mass.gov/eea/docs/doer/renewables/thermal/carts-report.pdf)

Solar Hot Water

Solar Hot Water	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	n/a	n/a	-$3	96,726	2.0
2020	n/a	n/a	n/a	$3	967,262	20
2030	n/a	n/a	n/a	$16	4,836,310	102

Data sources:

- Based on information from vendors

Thermal Biomass

Biomass Thermal	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	n/a	n/a	$9	31,550	83
2020	n/a	n/a	n/a	$9	15,775,000	41,325
2030	n/a	n/a	n/a	$8	31,550,000	82,650

Data sources:

- Based on Synapse expert judgment and on: the report to the Massachusetts legislature, *Heating and Cooling in the Massachusetts Alternative Portfolio Standard* and the *Commonwealth Accelerated Renewable Thermal Strategy* . (http://www.mass.gov/eea/docs/doer/pub-info/heating-and-cooling-in-aps.pdf) and on Navigant's 2013 *Incremental Cost Study Phase Two Final Report*, the *Commonwealth Accelerated Renewable Thermal Strategy* and information from vendors. (http://www.neep.org/sites/default/files/products/NEEP%20ICS2%20FINAL%20REPORT%202013Feb11-Website.pdf; http://www.mass.gov/eea/docs/doer/renewables/thermal/carts-report.pdf)

Gas Energy Efficiency: Residential

Res. Gas EE	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	n/a	n/a	n/a	n/a	n/a
2020	n/a	n/a	n/a	$4	1,275,955	701,775
2030	n/a	n/a	n/a	$2	3,344,095	1,839,252

Data sources:

- Based on LBNL's 2013 *The Future of Utility Customer-Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025.*

Gas Energy Efficiency: C&I

CI Gas EE	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	0.0	n/a	n/a	n/a	n/a
2020	0%	0	$0	-$2	1,303,881	717,135
2030	0%	0	$0	-$4	4,721,167	2,596,642

Data sources:

- Based on LBNL's 2013 *The Future of Utility Customer-Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025.*

Gas Energy Efficiency: Low Income

LI Gas EE	Annual Capacity Factor	Total Potential Capacity	Annual Net Levelized Cost	Annual Net Levelized Cost	Annual Energy Production	Peak Hour Gas Savings
	%	*MW*	*$/MWh*	*$/MMBtu NG*	*MMBtu NG*	*MMBtu NG*
2015	n/a	n/a	n/a	n/a	n/a	n/a
2020	n/a	n/a	n/a	$8	163,389	89,864
2030	n/a	n/a	n/a	$7	591,610	325,385

Data sources:

- Based on LBNL's 2013 *The Future of Utility Customer-Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025.*

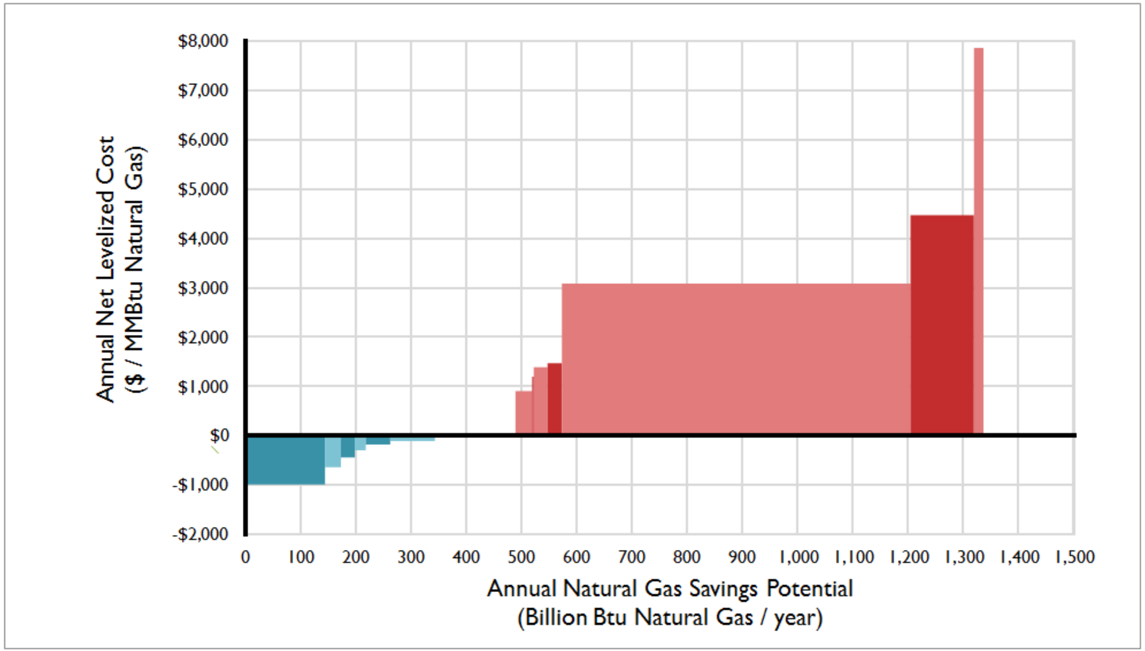
Supply Curves

Threshold for Economics Feasibility

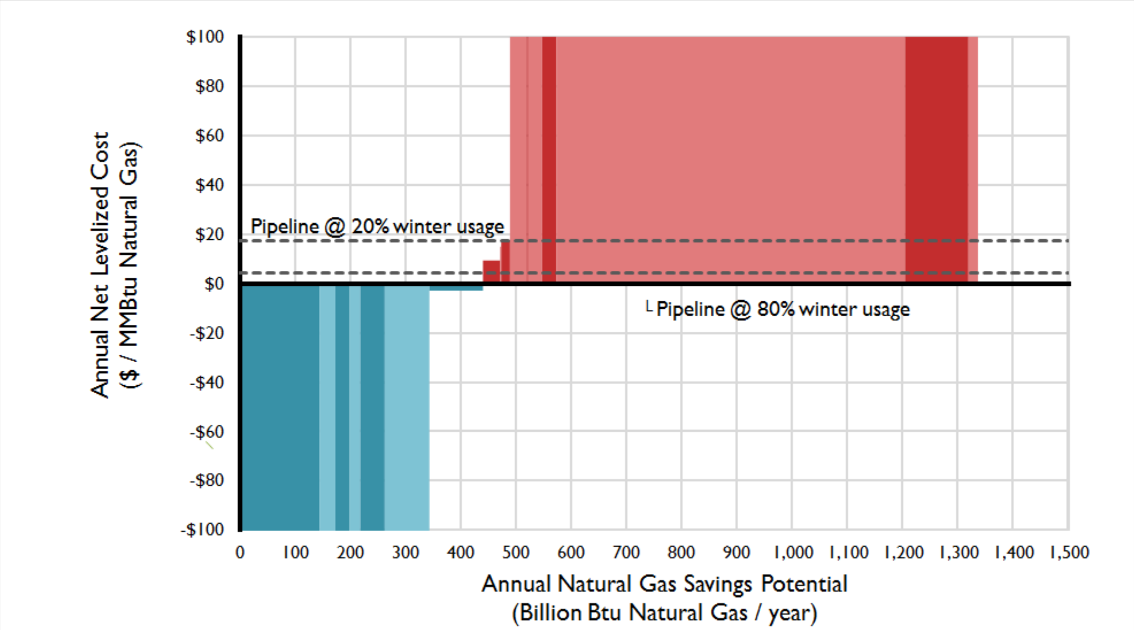
- Potential thresholds for economic feasibility include the average annual per MMBtu costs of incremental natural gas pipeline construction at two capacity levels:
  - 95 percent on 80 percent of winter days (chosen to represent the level of pipeline utilitization at which operational flow orders are typically declared and shippers are held to strict tolerances on their takes from the pipeline): $4/MMBtu
  - 95 percent on 20 percent of winter days: $18/MMBtu

- Data source: Based on Algonquin Incremental Market costs

2015 Supply Curve *(Billion Btu Natural Gas Savings Potential per Year versus Annual Net Levelized Cost)*

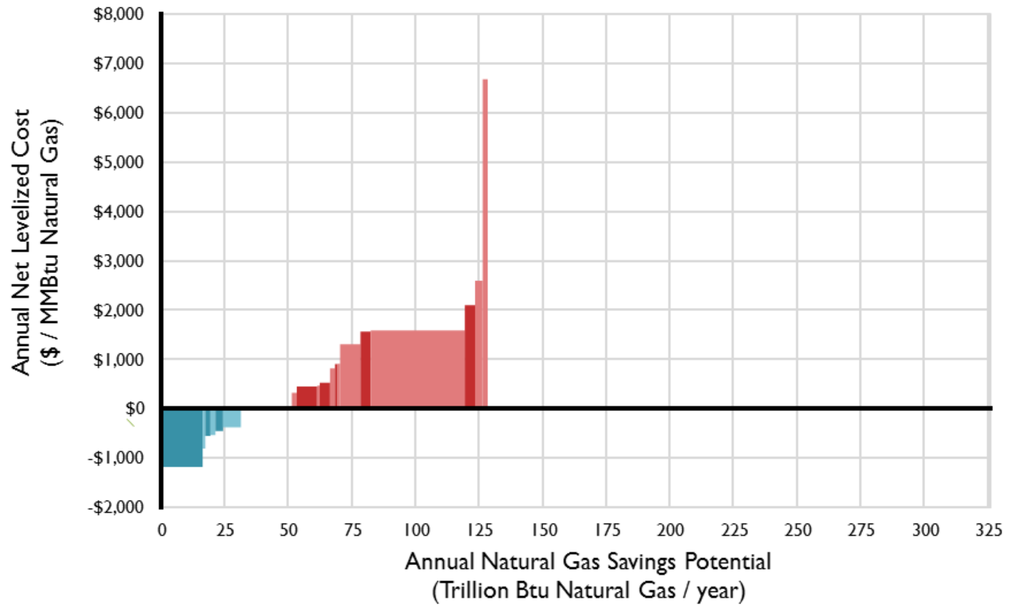


This chart zooms in to the marginal resources. The y-axis is truncated, but the x-axis is unchanged.

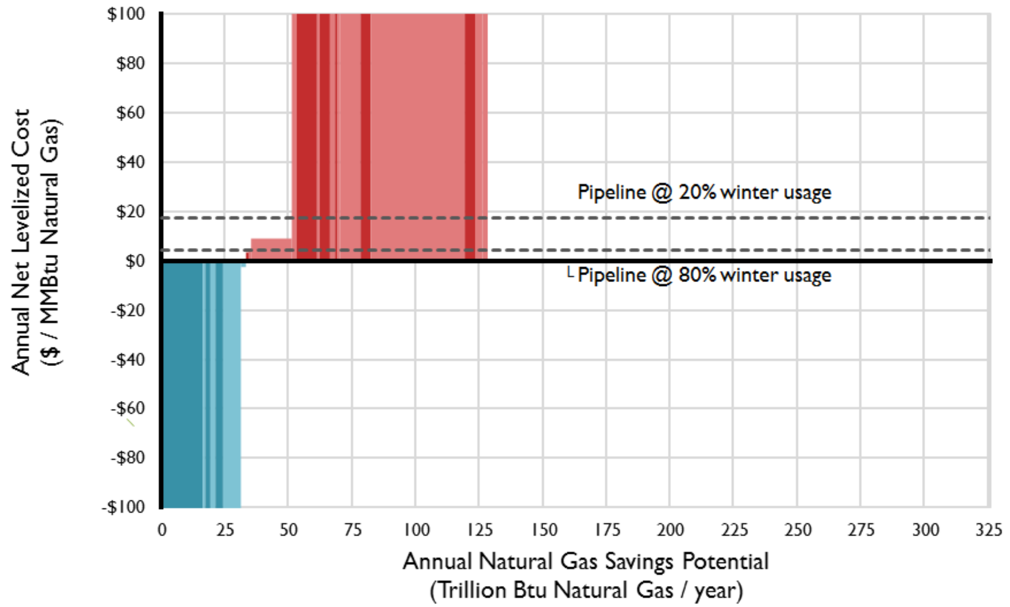


		Annual Net Levelized Cost ($/MMBtu)	*Annual Savings Potential (trillion Btu)*
1	CI Electric EE	-$988	145
2	Anaerobic Digestion	-$640	28
3	Landfill Gas	-$442	25
4	Converted Hydro	-$295	20
5	Small CHP	-$179	45
6	Res. Electric EE	-$105	81
7	Solar Hot Water	-$3	97
Pipeline @ 80% winter usage		$4	
8	Biomass Thermal	$9	32
9	GS Heat Pump	$15	2
Pipeline @ 20% winter usage		$18	
10	AS Heat Pump	$18	16
11	Commercial PV	$905	30
12	Residential PV	$1,198	3
13	LI Electric EE	$1,388	24
14	Wind (<100 kW)	$1,473	26
15	Battery Storage	$3,086	631
16	Elec DR	$4,475	115
17	Wind (<10 kW)	$7,866	17

2020 Supply Curve *(Trillion Btu Natural Gas Savings Potential per Year versus Annual Net Levelized Cost)*

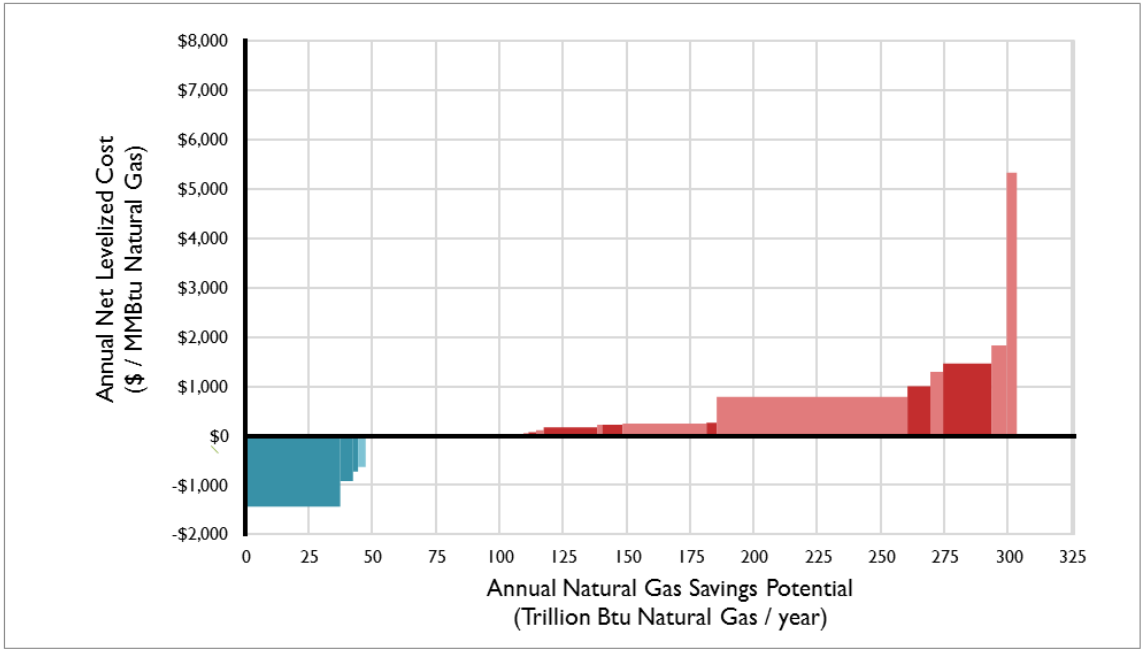


This chart zooms in to the marginal resources. The y-axis is truncated, but the x-axis is unchanged.

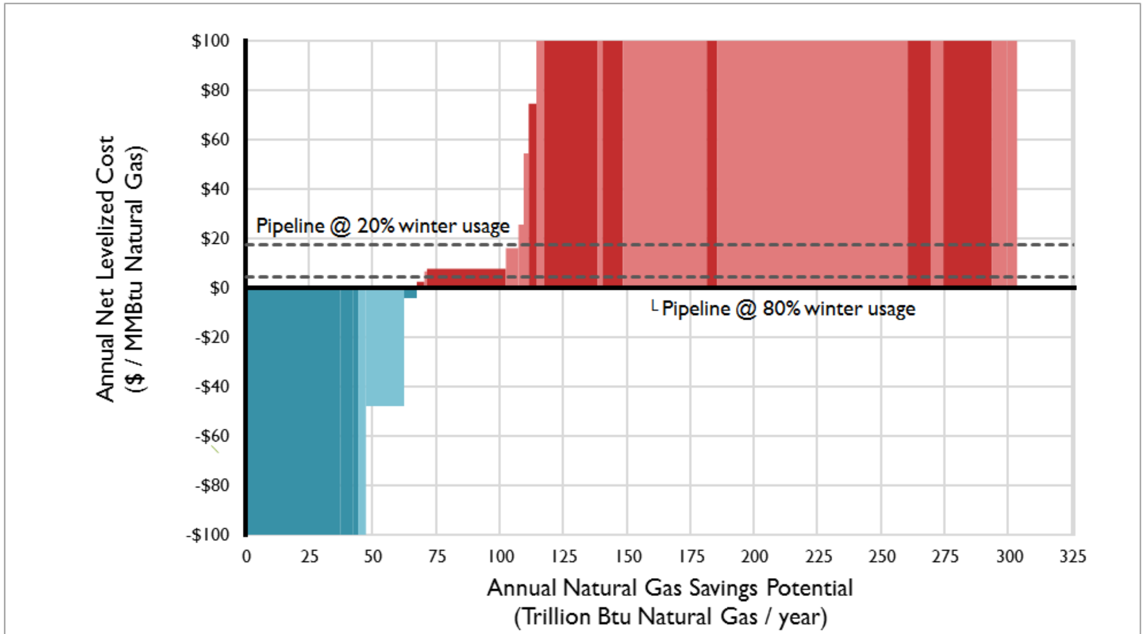


		Annual Net Levelized Cost ($/MMBtu)	*Annual Savings Potential (trillion Btu)*
1	CI Electric EE	-$1,181	16
2	Anaerobic Digestion	-$807	2
3	Landfill Gas	-$552	2
4	Large CHP	-$533	2
5	Converted Hydro	-$449	2
6	Res. Electric EE	-$377	7
7	Small CHP	-$41	0.04
8	CI Gas EE	-$2	1
9	Solar Hot Water	$3	1
10	Res. Gas EE	$4.15	1
Pipeline @ 80% winter usage		$4	
11	LI Gas EE	$8	0.16
12	Biomass Thermal	$9	16
13	GS Heat Pump	$16	0.06
Pipeline @ 20% winter usage		$18	
14	AS Heat Pump	$20	0.32
15	Winter Reliability	$36	0.03
16	Biomass Power C1	$322	2
17	Large Wind C5	$455	9
18	LI Electric EE	$469	1
19	Biomass Power C2	$530	3
20	Wind (<100 kW)	$820	3
21	Commercial PV	$905	1
22	Utility-Scale PV	$911	0.31
23	Residential PV	$1,084	0.07
24	Pumped Hydro	$1,307	9
25	Biomass Power C3	$1,566	3
26	Offshore Wind	$1,591	37
27	Biomass Power C4	$2,102	4
28	Battery Storage	$2,599	3
29	Elec DR	$4,316	0.12
30	Wind (<10 kW)	$6,683	2

2030 Supply Curve *(Trillion Btu Natural Gas Savings Potential per Year versus Annual Net Levelized Cost)*



This chart zooms in to the marginal resources. The y-axis is truncated, but the x-axis is unchanged.



		Annual Net Levelized Cost ($/MMBtu)	Annual Savings Potential (trillion Btu)
1	CI Electric EE	-$1,439	37
2	Anaerobic Digestion	-$1,155	1
3	Large CHP	-$918	4
4	Landfill Gas	-$820	0.50
5	Converted Hydro	-$724	2
6	Res. Electric EE	-$633	3
7	Small CHP	-$260	0.04
8	Commercial PV	-$48	15
9	CI Gas EE	-$4	5
10	Res. Gas EE	$2	3
Pipeline @ 80% winter usage		$4	
11	LI Gas EE	$7	1
12	Biomass Thermal	$8	32
13	Solar Hot Water	$16	5
Pipeline @ 20% winter usage		$18	
14	GS Heat Pump	$21	0
15	AS Heat Pump	$26	2
16	Winter Reliability	$36	0
17	Biomass Power C1	$55	2
18	Residential PV	$75	3
19	Utility-Scale PV	$116	3
20	Large Wind C5	$171	21
21	LI Electric EE	$224	1
22	Wind (<100 kW)	$226	8
23	Large Wind C4	$247	34
24	Biomass Power C2	$262	3
25	Offshore Wind	$788	76
26	Pumped Hydro	$1,007	9
27	Biomass Power C3	$1,299	5
28	Battery Storage	$1,467	19
29	Biomass Power C4	$1,835	6
30	Elec DR	$4,058	0
31	Wind (<10 kW)	$5,331	3

Q&A: Feasibility Analysis

Stakeholder Group Breakouts

- Groups:
  - Environmental/Consumer NGOs & Citizen Groups/Individuals
  - State Agencies & Local Government
  - Gas Industry
  - Electricity/Transmission Industry
  - Note: If you don't neatly fit into any of these groups, choose one to participate in
- Introductions (name, organization)
- Share perspectives with each other on Synapse Feasibility Analysis, including:
  - Avoided costs
  - Resource selection/assessments
  - Thresholds
  - Supply curves
- Develop set of group comments (even if range of opinion on an issue) and select 1-2 people to provide 5 minute summary to Synapse, DOER, and full group

Break

Small Group Break-Out

Wrap-up & Next Steps

Remaining Steps in Modeling/Analysis

1. Development of base case and sensitivity assumptions
2. Feasibility study of alternative resources in a low energy demand case
3. **Scenario modeling of eight scenario and sensitivity combinations**
4. **Assessment of natural gas capacity to demand balance in a winter peak event**

Schedule, Materials and Comments

- Stakeholder process materials available on the Synapse website at: http://synapse-energy.com/project/massachusetts-low-demand-analysis
- Written comment deadline for today's meeting: November 4, 5 PM
- Send comments to: lowdemandstudy@state.ma.us
- Remaining Stakeholder Meetings:
  - Nov. 20th (9-4) Location: TBD
- Final Report: Dec. 23rd